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EFFECTS OF MARTIAN DUST ON POWER SYSTEM COMPONENTS

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Manned exploration of the Martian surface as envisioned by the Space Exploration Initiative proposed by President Bush in 1989 will require large amounts of power. In contrast to the Viking landers, which used about 70 watts of power, most scenarios of a manned Martian mission envision power systems generating hundreds of kilowatts. Radioisotope thermal generators (RTG's) which were so successful in providing the Viking landers with power, will have to be supplanted with larger power systems based on large photovoltaic arrays coupled to regenerative fuel cells or with nuclear reactors. Before these large power systems can be put into place, it must be determined how their performance will be affected by the Martian environment.

There are several hostile elements within the Martian environment which have the potential to degrade the power system. These include wide daily temperature swings (up to 50 K), ultraviolet radiation, high energy particle radiation, high velocity winds (albeit at low pressure), chemically reactive species in the soil, atmospheric condensates, and dust storms. At NASA Lewis we have initiated a program to assess the impact of these environmental factors on power system performance. It is also part of our goal to find ways to mitigate these degradative effects.

The effects of blowing dust on photovoltaic (PV) and radiator surfaces is the subject of our initial work. In this work we have made extensive use of the Martian Surface Wind Tunnel (MARSWIT) located at NASA Ames Research Center to simulate Martian winds. To date we have run two basic types of experiment sets. In the first, we have studied the threshold clearing velocity of dust deposited on PV coverslip materials and high emissivity radiator materials in clear Martian-like winds. In the second, we have dropped dust near the inlet of the wind tunnel and allowed the winds to carry the dust past the samples, simulating a dust storm. Below is a summary of our results.

In order to test the ability of the wind to remove dust from surfaces, dust must first be deposited on those surfaces. In order to most closely simulate the way that dust would deposited on a surface after a storm, a dust deposition box was constructed. The box has three principle components, an inverted square pyramidal base, a 1 meter high upper chamber, and a sliding drawer. A quantity of dust is first placed in the bottom of the inverted pyramid. A blast of dried air is directed downward onto the dust with sufficient force to elevate the dust into the upper chamber. The air is then turned off and the dust allowed to settle out. Stokes law tells us that large particles will fall the fastest, so for the first 15 seconds the larger particles and conglomerates are allowed to fall back into the inverted pyramid. The drawer holding the samples is then slid into the path of the falling dust so that the fine particles settle onto the sample holder. See NASA CP-3096 (1990) p. 447, for additional information.

Three different types of dust were used. In the initial experiments, an aluminum oxide based optical polishing grit with a size range of 1.5 to 30 μm was used. This material does not easily form agglomerates in air and so was easy to work with. In later experiments a basaltic dust of the same approximate size was used because its chemistry is similar to that of Martian dust. Finally, very fine grained (0.3 to 3 μm) ferric oxide powder was used.

In the first series of tests, optical polishing grit was deposited six different types of PV coverslips and three different types of high emittance radiator surfaces. The height from the MARSWIT floor, angle of attack, and wind velocity were all varied in an attempt to determine the important parameters. It was found using optical transmittance that the PV coating material and height from the MARSWIT floor were only minor influences in the clearing of dust from these surfaces. Angle of attack and wind velocity were found to be the major influences. The wind velocities of 55, 85, and 124 m/s were found to be sufficient to clear most of the dust off of the PV surfaces within a few minutes.

In the second series of tests, lower velocity winds were used (10, 30, and 35 m/s). At 10 m/s, virtually no clearing occurred. A small amount of clearing occurred during the 30 m/s test, and considerably more at 35 m/s. The threshold value varies with angle of attack, and at 45°, that value is near 35 m/s. The clearing dropped both at lower and at higher angles. In those samples where the dust removal was incomplete it was noted that the dust appeared to be lifted directly upward from the surface. This seems to implicate and aerodynamic lift mechanism which plucks the dust particles directly off of the surface before the wind stream carries it off. Evidence was also found for a second dust removal mechanism. At lower velocities the dust left streaks in the wind direction, indicating perhaps that the dust particles "roll" along the surface for a short distance before they are lifted up into the wind. Evidence for this was seen only in the low angle (22.5°) sample. During the second set of tests a turbulence fence was introduced with the idea to induce clearing at lower wind velocities by providing regions of high local velocity. However, it was found that the turbulence fence actually raised the threshold clearing velocity instead of lowering it. These experiments are summarized in NASA TM-102507 (1990).

The goal of the third series of tests was to examine the sensitivity of the threshold clearing velocity to the composition of the dust. Thus, in addition to the optical polishing grit, basalt and ferric oxide dusted samples were placed in the MARSWIT. The threshold clearing velocity of the basalt was very similar to the optical polishing grit, ranging between 30 and 40 m/s for a 45° angle. The threshold clearing velocity for the ferric oxide was much higher (between 85 and 95 m/s), but it is unclear how much of the effect is due to chemistry and how much is due to particle size effects. These two samples did, however, confirm that the optimum angle for dust clearing is something near 45°. It appeared from these tests that of the two dust removal mechanisms that the "rolling" mechanism has a lower threshold velocity, but that the "aerodynamic" mechanism is more efficient and so dominates at higher velocities. Degradation of the emittance of radiator surfaces was also observed. It was found that ion beam textured graphite and carbon-carbon composite samples degraded less that did arc-textured copper or niobium-1%-zirconium. This was due to the abrasion of the carbon from the surface of the arc-textured metal samples, which lowered their emittance appreciably. The radiator work is reported in NASA TM-103205 (1990), and PV work in NASA CP-3096 (1990) p. 379.

The fourth test series examined the effects of blowing dust on PV and radiator surfaces. It was found that exposure to dust laden wind changed the dust clearing behavior of the samples. Initially clean samples became dusty even when they were exposed to winds well above the threshold clearing values (97 m/s). Initially dusted samples partially cleared well below the threshold velocity (19 m/s). Samples tended to converge to an equilibrium dustiness independent of their initial condition, but dependant upon the wind velocity. It was found that abrasion was much more of a problem with both arc-textured metals, and glass coverslips. Interestingly, it was found that an initial coating of dust actually reduced the amount of abrasion, at least in the case of arc-textured radiator samples. NASA TM-103704 (1991) summarizes this work.

The most important information we have learned to date is that interactions between the wind-blown dust on Mars and power system components are complex. We do not yet have answers even to the extent of the problem. The results of these types of tests have far-ranging implications for the design of the power system, and thus this work needs to be performed during the early stages of system design.